



Frontiers of Space Access/Utilization/ Exploration Technologies

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“Spaceship Earth”

The crew are:

- **Plundering the ship's supplies**
- **Tinkering with the temperature and life-support controls**
- **Still looking for the instruction manual**
- **Engaging in bloody skirmishes in every corner of the vessel**
- **Increasing the size of the crew by 2 million PER WEEK**

- P. Creola

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Technological Ages of Humankind

- Hunter/Killer groups [Million BC~10K BC]
- Agriculture [10K BC~1800 AD]
- Industrial [1800~1950]
- IT [1950~2020]
- Bio/NANO [2020-?]
- Virtual

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- Hunter-Gatherer - “Nature Provided”
- Agriculture - Controlled Nature (Plants/Animals)
- Industrial - Mechanized Agriculture
- IT/BIO/Nano - Automating Industry/Agriculture
- Virtual - Robotization of IT/Bio/Nano/Industry/Agriculture

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Humans Have “Taken Over” and Vastly Shortened “Evolution”

- Of the Planet
 - Global Warming/Pollution/Deforestation
 - Huge “Public Works” (e.g. 3 Gorges Dam)
- Of the Human Species
 - Genomic Design and Repair
 - “Mind Children” (Moravec)
- Products/Life Forms
 - Cross Species Molecular Breeding
 - “Directed Evolution” (Maxygen etc.)

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KEY “FUTURE TECHNOLOGIES” *(all highly synergistic/at the frontiers of the small, in a “feeding frenzy” off each other)*

- IT
 - Silicon/bio/optical/quantum/nano computing (“no end in sight,” another 10^6 +)
 - (Virtual reality/holographic) immersive ubiquitous comms., hyperspectral sensors, “virtual presence”
 - Automatic/robotic “everything”
 - Huge cost reductions
- Bio
 - Life span doubling
 - Genetic engineering before birth
 - Plants irrigated by seawater (food, petro-chem feed stock, minerals, terraforming)
- Nano
 - Carbon nanotubes (600X strength-to-weight of steel)
 - “Assemblers”/“living factories”
 - Huge cost reductions

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VIRTUAL REALITY OUTLOOK

- **Optical Comms - Bandwidth**
- **“Conventional” VR/next 10 years**
 - **“3-D” Sound, Smell, Haptic Touch**
 - **Projection onto eye**
 - **Better/more intense than Reality**
- **Beyond Conventional**
 - **Direct Brain Feeds**
 - **“Super Sensory” inputs/experiences**
- **Applications Include Entertainment, Travel, Business, Medicine, Education, Creativity**

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Nano Technology

- **Coatings/Barriers** (thermal, radiation, abrasive, recording, combined sensors/ effectors/signature/comms, single molecule sensors)
- **Computers** (Molecular/Petaflop and beyond Computing)
- **Materials** (SWCNT's, Ultra high strength-to-weight, High Surface area for catalysis, sieves, filters, absorption)
- **“Assemblers”?** (Changes EVERYTHING -- e.g. Economics, Exploration, Manufacture)

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Carbon Nanotubes

- C1,000,000, Buckminster Fullerene Carbon
- 100X strength, 1/6 weight of steel
- 8X better Armor
- Low energy Molecular/Petaflop Computing (10^{-4} En. Usage)
- Ultra Capacitor/High Temperature SC

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DOE [A.D. 2000]

Graphite nanofibers which store
3X weight of H₂

[Fuel & Rad Protection, Spacecraft
and EVA suits]

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Sensor Trends

- Mini-to-Micro-to-Nano
- Hyperspectral
- Multiphysics
- Hypersensitive (E-6 F IR Nano cantilevers)
- Integrated with Actuators
- “Off-Board” Sensor Webs/Swarms (Contextual/Anticipatory)

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Actuator Trends

- Discrete-to-Distributed
- Mini-to-micro-to-?
- Amplitude/Gain increase (Bifurcations/Saddle points)
- Mechanical-to-E/M-to-E/chem/bio?
- Energy Regenerative/reduction/generation
- Structural Integration (Strength Increase?)
 - Room Temperature S/C E-M?

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Free Form Fabrication

- **Powder/Wire Metallurgy using robotic magnetically steered electron beams to create accreting local melts - GROW instead of CUT**
- **No fasteners, no strong backs for fasteners**
- **Nearly infinite fatigue life, excellent metallurgy**
- **(Repairable) metals at lower weight than far more expensive composites**

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“Givens” (Now-to-Soon)

- **Gb data transfer rates, optical comms**
- **Teraflop-to-petaflop computing**
- **Exceptional AI (from Bioinformatics, biomimetics)**
- **Wonderous/Ubiquitous/inexpensive land/sea/air/space multiphysics/hyperspectral sensor swarms (military/commercial/scientific)**
- **Robotics/swarm technologies primarily commercial/endemic worldwide**

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What Would Be “Exciting”?

- Energy to Earth from space (He₃, solar, zero pt. eng)?
- Virtual presence (immersive) for public
- Discover
 - Life (carbon or non-carbon based)
 - Breakthrough materials, ala He₃ on moon
 - New energy sources
- Humans emigrate/colonize other worlds (safely and affordably)
- “Planetary defense” (from asteroids etc.)
- UFO’s exist (e.g. intelligent life “wandering around”)
- Discover new physical phenomena (space warps, space worlds, or ?)

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The Importance of Revolutionary Technology

- Exploration funding Realities:
 - Tax Cuts Will Ensure Level Budgets
 - “Due Bills” for station/shuttle will Ensure limited Exploration Budgets
- Simplex Current Exploration Status:
 - What is affordable is not safe
 - What is safe is not affordable
- Revol. Goals (Both Safe & Affordable) require Revol. Technology

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Ongoing Changes/Options in Space Utilization & Economics

- From IT/Bio/Nano - Payloads which are much Smaller/Lighter/Smarter/Cheaper
- Results in increasing “Value per pound” and less pounds (Utah Company offering 4” sats for 45K including the “ride.”)
- Decreasing rational for “Humans in Space” (Robotics MUCH “better/cheaper/faster”)
- Revol. Rocket & “Mass Launch” Options
- Reusable In-Space Infrastructures (Fuel Depots, “Beamers,” Insitu free form fab.)

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“Givens”

- Strive for REUSABLE (include In-Space) INFRASTRUCTURE (Commercial, Scientific, Military, Other Govt.)
 - Propulsion, ISRU, Shelters, Flyers, Rovers, Etc.)
- “Full Court” Utilization/Leveraging of the on-going IT/Bio/Nano Tech Revolutions (incl. Smart Dust, Moletronics) to reduce size/wt./power req., increase capab.
- “Leveraging” of Commercial, Military, non-Aerospace Investments

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“Metrics”

- **Reduced Cost(s):**
(Reduced design/manuf. costs, red. weight, part count, power req., support, “standing Army”)
- **Improved Safety:**
(Abort options, Radiation/microG, Reliability in the “Real World” “Out There”)
- **Increased “Productivity”/ROI**

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(Simplistically) “Need”

- **“Cheap” Energy/power**
- **Light Weight**
- **Reliability**

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Advanced Technology Categories

- **Propulsion (ETO, In-space)**
- **Energy Storage/sources**
- **Materials/Fab.**
- **On Planet ops/“Stuff”**
- **Radiation/Micro g Protection/Mitigation**
- **Spacecraft**
- **Architectures/Systems/“Concepts”**

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**If God had wanted
people to go to Space,
She would have given
them more Money**

*Mark Albert
Scientific American*

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Two Disparate Space Access Missions

- Civilian/Military (nearer-to-mid-term)--
“Inexpensive” space access, ≈ \$100/lb.
(Revolutionary Rocket and/or very advanced fuels)
- Military (somewhat farther term)--
(Affordable) space warfare, “flexibility metrics” (Airbreather and/or advanced fuels)

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ACCESS TO SPACE THE METRICS

CIVILIAN AND MILITARY

- Inexpensive (\$100/lb)
- Reusability
- Improved
 - Safety
 - Reliability
 - Frequency of operation/rapid turnaround
- Simplified ground ops/reduced “standing Army”
- Environmental compatibility
 - Chemical
 - Debris
- Safe abort/assured payload return

FLEXIBLE MILITARY (2ND GENERATION “SPACE PLANE”)

- Reduced glow/size (handling/hiding)
- Reusability
- All azimuth/inclination launch
- Improved
 - Safety
 - Reliability
 - Frequency of operation/rapid turnaround
- Enhanced launch windows
- Self-ferry
- Hypersonic cruise
- Simplified ground ops/(storable fuels?)
- Large cross range
- Increased launch site options
- Orbital plane change
- Launch on demand
- Orbit, de-orbit, re-orbit
- Safe abort/assured payload return

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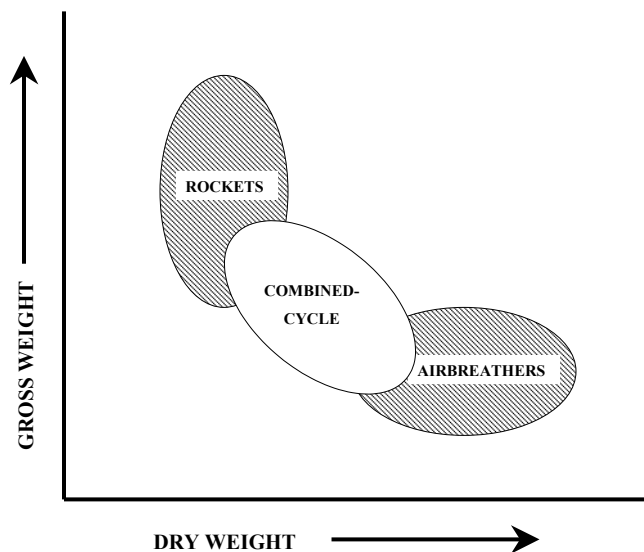


ACCESS TO SPACE *THE (USUAL) DESIGN OPTION*

- Rockets (various)
- Airbreathing (various)
- Staging (single, two, three, etc.)
- Reusable/expendable
- Horizontal/vertical T/O and landing
- Fuels (various)
- Manned/unmanned
- Materials (various)
- Controls (various)

Thus far--no clear “winning combinations” for either affordability or flexibility metrics, are agonizing along evolutionary development paths, worldwide

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POTENTIAL FOR COMBINED-CYCLE PROPULSION

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Airbreather Issues

- **Increased Engine/Dry Weight**
- **Increased Maintenance**
- **Large Development costs**
- **Unknown, but worrisome, thermal-acoustic fatigue problems**

Overall - Increased Cost (but greater “Flexibility”)

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NASA Gen 2/3 ETO Program Comments

- **Major disconnect(s) between goals (1/100 cost, 1000X safety) and program content**
- **The “Health monitoring” (IVHM) etc. bits are good/will reduce cost(s)**
- **The RBCC parts will probably INCREASE cost/reduce safety (Cannot test on ground, Development costs, greater Engine dry wt., incr. Maintenance)**
- **No Requisite “paradigm-busting” Content, Hence no source(s) for Huge Improvements to meet goals**

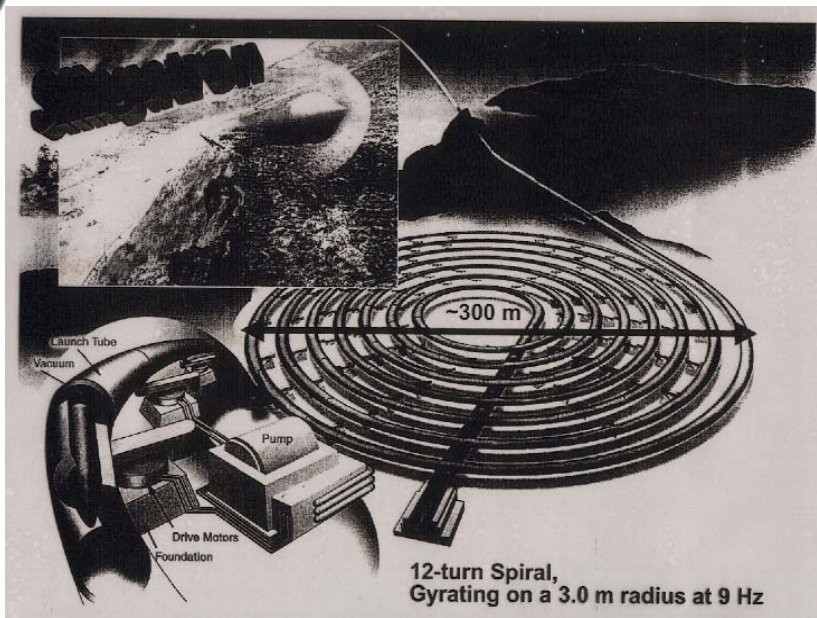
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“Revolutionary (ETO) Rocket”

- PDWR, Deton. In Liquid fuel, Red. Fuel pump pressures
- Hypermixing Base Ejector/augmentor (X2 payload)
- Fuel - Isomers, LENR, HEDM (Various)
- “Designer Aero,” obviate ballast/packaging
- Syntactic Foams, CNT’s
- *Looooong* CNT elec. Cable left attached during some of ascent (self supporting) to feed energy into an MHD base accelerator (ISP - 2500 sec.)

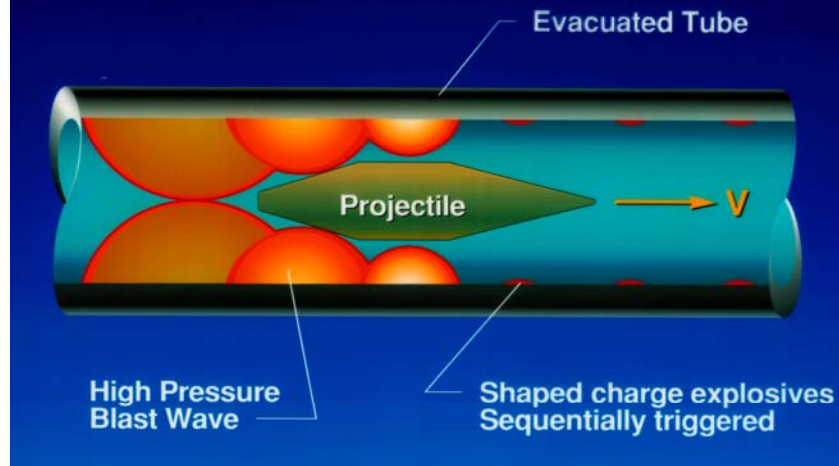
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BLAST-WAVE ACCELERATOR



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“Beamers”

- Reusable Commercial/Military etc. Infrastructure
- In-Orbit Beaming Sats (Earth and Planet)
- Solar or “Fueled”
- Either:
 - Free Electron Lasers w/Narrow Band PV's OR
 - AC MW with Rectennas
- “Off Board” energy to power an MHD nozzle Accelerator for ISP = 2500 sec. High thrust Chem.
- Water for Antenna cooling, Radiation Protec., Fuel
- Allows High g Acceleration out of Gravity Well(s) and orbit raising/maneuvering
- In-Space “Beam Lenses”/Concentrators

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Revolutionary Power Generation/Storage Opportunities

- Ultracapacitors
- Adv. Fuel Cells (e.g. Lithium/water/air)
- HEDM (e.g. Solid H₂, Isomers, anti-matter, etc.)
- Adv. PV (50%?)
- Room Temperature SC/SMES
- C-Nanotube storage of H₂ (non-cryo)
- LENR
- ZPE

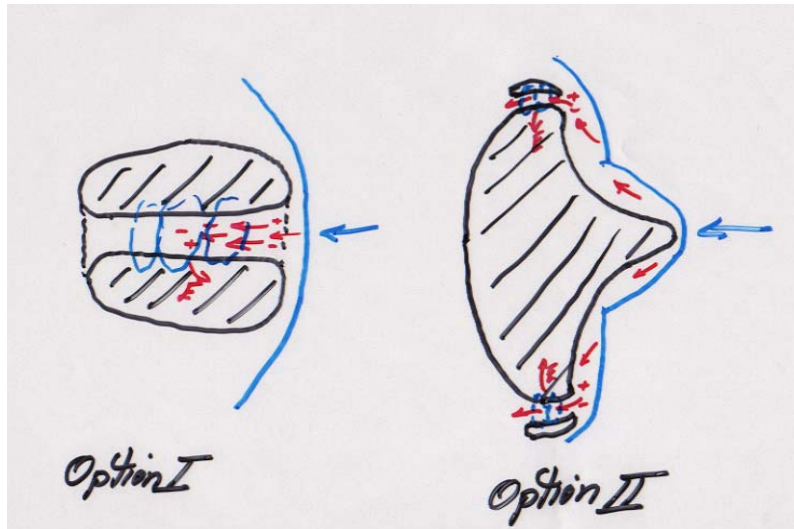
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A “New” Idea?

- **Regenerative Aerobraking at MARS:**
 - Next step in progression from retro rockets (where add energy) to (conventional) aerobraking (“energy neutral”) to Regenerative aerobraking (RECOVER Energy)
- Example approach - MHD generation, flywheel storage (or H₂/O₂ from H₂O or?)

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Possible MHD Synergisms

- **MHD Accelerator:**
 - In-space Propul. via Beamers
 - “Launch Assist” via Attached CNT Conductors
- **MHD Generator:**
 - Regenerative Aerobraking

Creative Design/Architectures could allow (re)utilization of MHD magnets etc. for launch inspace braking.

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Applications of CNT's

- **Overall weight Reductions order of 3 to 5**
- **Non-Cryo H₂ storage??**
- **Mag Sail**
- **[Better] Tethers**
- **IT/Sensor miniaturization/vast improvements/power reductions**
- **Launch Assist**

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“Mitigation” Genomics

1. **Selection/Tailoring within existing Gene Pool [including at “pre-conception” level], commission creation of astronauts**
2. **Genomic “treatments”[e.g. Radiation Protection Genomic treatment available for Cancer Patients to mitigate Rad. Therapy influences on normal tissue]**
3. **“Invention”/Creation of appropriate Genome alterations at pre-conception stage [“Designer Humans”] - Are we tracking the worldwide Research?**

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The Exploration “Frontiers”

- **“Roots” - ROOM Temperature S-C**
- **Genomics - Rad/Microg hardened Humans**
- **Aggregate Buildups for Economy of Scale**
- **CNT’s**
- **Moletronics**
- **Isomers, LENR’s, HEDM**
- **“Revolutionary Rocket”**
- **Free Form Fab**
- **Regenerative Aerobraking**
- **Reusable Infrastructures**

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“Frontiers” (continued)

- **Automatics/Robotics “In The Large”**
- **Orbital Beamers**
- **Total Recycling**
- **Optical Comms, Virtual Immersive Presence**
- **Symbolic Manipulation [Machines write the software]**
- **Nucs including Fusion [various flavors]**
- **M2P2 include Mag. Rad. Mitigation**
- **“Frontier” Solar**

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Revolutionary In-Situ Resource Utilization

- **In Situ Power Production**
 - In Situ Produced Solar Cells
 - Space Based solar using C-nanotubes to reduce structural weight
 - 150 degree F surface Temperature swings to power compressors
 - Mars Fe Rectennas (to receive power from Solar Electric Propulsion Vehicles in Aerosync
 - Geothermal
 - Radiometric mills (operated by Martian dusty/electrically active winds)
 - CO₂-Mg Heat Engines
 - CO₂-Li Fuel Cells
 - Geothermal
 - C-Nanotube H₂ storage & ultracapacitors
 - CO₂ in atmosphere solar pumped laser
- **Life Support**
 - Zeolite molecular sieve water extraction
 - Bio Engineered Plants for Mars Crops
 - Production and Storage of H₂O & O₂ at Outposts
 - Rapid Prototype Construction and Repair of Mars Habitats w/Mars Fe and Glass Powders
 - In Situ Produced C-Nanotube/H₂ Shielding
 - Inflatable habitats in Lava Tubes/caverns
- **In Situ Propellant Production**
 - Direct semi-conductor solar powered H₂ extraction from H₂O
 - Sample Return Propellant from Near Earth Asteroids
 - Mars Outpost Robotic Rover Propellant for CO₂
 - Asteroid Reaction Mass Acceleration to Change its Orbit
- **Non Ore Specific Differentiation**
 - Magma Electrolysis
 - Electronically Enhanced Sputtering
 - Plasma Furnaces
- **Manufacturing with In Situ Resources**
 - Manufacturing hopper vehicles in-situ
 - Production a high mass fraction of Rovers with In Situ Fe
 - Human in the loop replication of high mass fraction of human habitats
 - Free form fabrication/repair using Martian Fe and glass powders

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[Sample] Uses for Martian CO₂

- **Nuc Shielding**
- **Metal fuel cells**
- **O₂ Production**
- **C for CNT's**
- **Pressurized Rockets**
- **CH₄ fuel production**
- **In-atmosphere solar pumped CO₂ Laser**
- **Polyethylene Production**

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Some Bio Suggestions

- Search for/Utilization of Non-Carbon Based Life Forms
- Bio-engineered Plants for Planets
- Suspended Animation [depress hypothalamus to reduce body temperature and dehydration]
- Recycling of solids [feed to bugs, eat bugs - Excellent fat/protein source]
- Genomics for Immune function boosting

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Nutritional Supplements as Radioprotectors— A Review and Proposal

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Abstract

The scientific literature contains several reports that show nutritional substances, such as vitamins, minerals, and phytochemicals (plant chemicals), provide substantial radioprotective effects in animal studies. Incorporating these substances to the human diet, already voluntarily practiced by a large segment of the population, in addition to providing other favorable health effects, may also provide a radioprotective effect. This potential radioprotective effect would be very useful in mitigating the effects of occupational radiation exposure to astronauts (especially future Mars explorers), airline crews, nuclear workers, both commercial and government, and populations exposed to nuclear accidents, e.g. Chernobyl. This paper reviews the existing evidence of radioprotective effects by nutritional supplements and proposes that their efficacy be evaluated, first with animal studies, followed by human tests with astronauts and cosmonauts on long-term missions, such as to the Mir space station and the International Space Station (ISS).

1. Introduction

In the early 1950s, Lushbaugh and co-workers at the Los Alamos Scientific Laboratory (1,2) found that fresh aloe vera gel was very effective in aiding the healing of beta radiation-induced skin burns induced by exposure of rabbits to radioactive strontium. Healing times were cut to less than half. This discovery has led to the isolation of the active component of aloe vera gel, acemannan. A key discovery in more recent years is that administration of acemannan has shown strong radioprotective effects in rats subjected to sublethal doses of radiation (3). Acemannan is currently commercially available as a nutritional supplement, and acts as an immune system stimulant/modulator. Acemannan has been found to be non-toxic (4).

Hall (5) has reviewed chemical radioprotectors, with an emphasis on their use in radiotherapy. Amifostine (WR-2721) appears to be the best synthetic chemical radioprotector for radiotherapy. The structure of amifostine is $\text{NH}_2(\text{CH}_2)_9\text{NHC}(\text{CH}_2)_2\text{CH}_2\text{SPO}_2\text{H}_2$. Hall reports that Apollo astronauts probably carried WR-2721 to the moon to protect themselves from high-energy protons in case of a solar flare once outside the Earth's protective magnetic field. The astronauts would have been exposed to an estimated dose of several Grey (Gy), equivalent to several hundred rads, a potentially fatal dose. WR-2721 provides a Dose Reduction Factor (DRF) of two to three and would greatly reduce the health effects of a solar event. Unfortunately, chemical

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3 Major/Disparate Energy/Propul. Approaches

- 1. Quasi-Conventional (Adv. Solar, Beamers, Water/Chem., MHD, Depots, Geothermal, etc.**
- 2. (Fission) Nucs all-the-way (except ETO)**
- 3. Frontier Concepts - LENR's, Fusion(s), Isomers, Other HEDM, ?**

PLUS: - Major Public Works (tethers, “elevators,” etc.)

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“Preposition” Everything Possible/Reasonable [Safety]

- Comm/Nav/Solar Sats**
- ISRU “In The Large”**
- Return Fuel/Propulsion inc. beamers, tethers**
- Power**
- Habitats**
- Robotic Adjuncts**

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Fempto/ATTO-Second Lasers

- Order E-15 Pulse Length
- Improved Atmospheric Propagation (< breakdown time), “Pre-Plasma Channeling”
- Can “cut through anything,” 100 Terrawatt to Petawatts per pulse
- Wholly new/different material Interactions/Kill Mechanisms, no “protective plasma layer” formation, Huge localized electrical/magnetic fields (>atomic forces)
- Can be small/inexpensive

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Fempto/ATTO-Second Lasers Applications

- Sensing
- Laser and (from “secondaries”) - gamma/x-ray (effective defense against hordes/swarms weaponry)
- Fission ignition (accomplished)
- Enables new neutron, positron, x-ray and gamma ray sources
- Fusion ignition/thermonuclear
- Broaching, “make safe”
- Comms
- Beamed propulsion
- Materials processing and “machining”
- Medical applications

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Advanced SPACE Technology Rackup

- **Space Access** (Blast Wave Accelerator/\$50/Lb, Tether Cable Catapult, Solid H² Fuel/2000 sec., PDWR/Liq. Fuel, Ejectors, C-nanotubes)
- **Interplanetary Flight** (H² Rad. Shielding, Magnetic Sails, Aerobraking, Tether Propulsion, Isomer Propulsion, High(er) Thrust Electric/Mag. Nozzles, C-nanotubes, Recycling/liquids/gases/solids?)
- **Exploration Ops** (In-situ resources/including Return Fuel, Bio-Engineered Plants, Geothermal for Mars, C-nanotubes, Virtual Presence/Robotic/AI+)
- **Interstellar Flight** (D-He³ Fusion, Anti-matter, Beamed Energy)

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Far(ther) Term

- **Nano self assemblers including ISRU**
- **“Beyond Human” AI, Cyber/Artificial [non-anthropomorphic] sentient “Life”**
- **Fusion, Anti-matter Propulsion**
- **ZPE**

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Potential Commercial/Military Reusable Space Infrastructure(s) and Opportunities

- **Fuel Depots**
- **Beamers**
- **Tethers**
 - **For In-space propul., Orbit raising, Maneuv.**
- **Reusable Revolutionary ETO Rocket**
- **Virtual/Immersive Telepresence**
- **Space Solar Power**
- **“Discoveries” [Materials, energy, Life forms]**

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The ISSUE

- **Capabilities of “Learning”/Adaptive
AI/Robotics as a function of time**
[Huge Commercial/Foreign Investments
with tremendous “promise”]
 - **For “Aid and Comfort” to Human Ops**
 - **As Replacements for Humans for
“Discovery,” The “Unexpected”**

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What Supplies the Brilliance?

- **Conventional - Increasingly capable/miniaturized computers/processors**
 - E6 since '59, E6 to E8 on the Horizon (Silicon/optical/bio/nano/molec./quantum)
- **Unconventional/Emerging**
 - Artificial Life/“Cyber Life”
 - Directly from the brain

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AI (AND BEYOND) COMPUTING

Human Brain Characteristics/Capabilities

- 100 billion neurons
- 100 trillion connections
- 200 calculations/second, (slow) speed of neural circuitry
- 20 million billion calculations/second
- Excellent at (parallel-computing) pattern recognition, “poor” at sequential thinking
- Operates via “random tries”

Machine Capabilities

- Currently, 10,000 billion calculations/second; 100,000 billion by 2004
- By 2010, 20 million billion is available (by 2025, on a PC)
- By 2030, PC has collective computing power of a town full of human minds

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U.S. “HUMAN BRAIN PROJECT”

- Begun in early 90’s, funded by 16 organizations across 5 agencies (NIH, NSF, DOD, NASA, DOE)
- AKA “Neuroinformatics” (intersection of neuroscience and informatics)
- “Exploding field;” 10,000 individual presentations at annual meeting of Society for Neuroscience (from molecular geneticists to cognitive psychologists)
- Determining detailed neuroanatomy of human brain (“digital brain atlas”)
- Use of IT to study brain, use of brain info to aid IT/AI

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THE “IMAGINATION ENGINE” *aka “Creativity Machine,”* *aka “Creative Agent”*

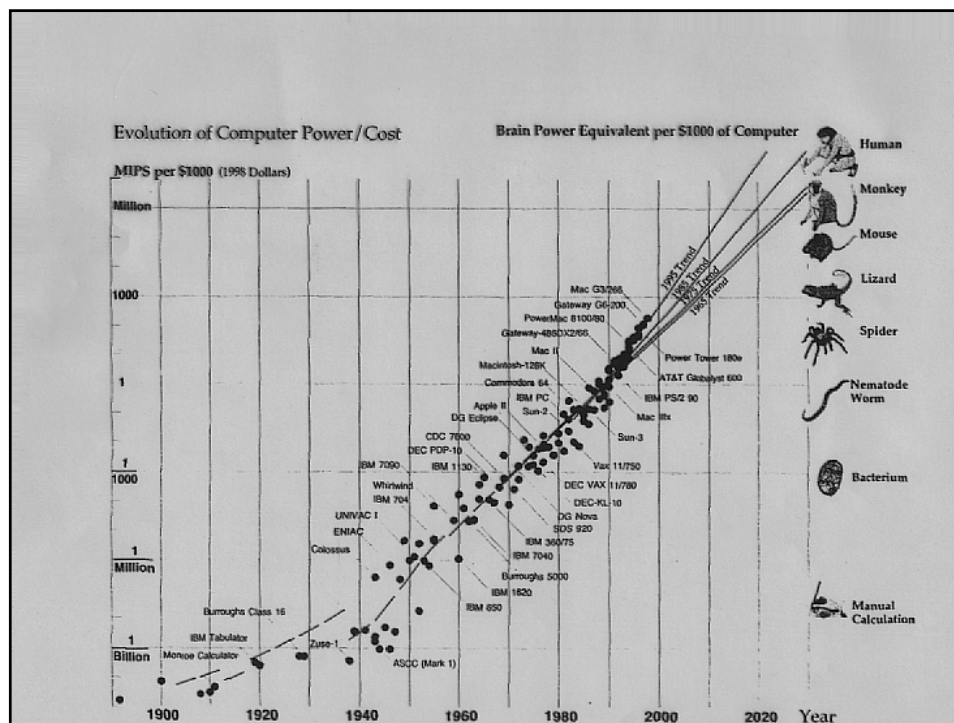
- Current AI “best bet,” not a rule based/expert system
- GENERATES new ideas/concepts via starving a trained neural net of meaningful inputs, forcing it to “dream”/“cavitate,” create new concepts, etc. An attendant neural net used to capture/record/evaluate and report on these “writings.”

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- **Two “flavors”**
 - **Traditional AI - Rule Based**
 - **Experiential - Behavior Based (Neural Nets/other “Soft Computing”**
- **Combination of these is current “best bet” (per Moravec) to produce artificial/cyber “life” which will possibly-to-probably be sentient but will not be anthropomorphic**

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“Humankind”

- **Evolved as Dominant Animal on Planet:**
 - **Social/Hunter-Killer GROUPS (Mental Development)**
- **Will Evolve?:**
 - **Initially into “Augmented” Bodies/Minds (Cyborgs)**
 - **Eventually into Hans Moravec’s “Mind Children?”**

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Human Evolution?

- | | |
|-------------------------------|----------------------------------|
| • <u>BODY</u> | • <u>MIND</u> |
| – Wet Electrochemistry | – Wet Electrochemistry |
| – Plus | – Plus |
| • Repair/Replacement | • Off-board Adjuncts |
| • Augmentation | • On-board Adjuncts |
| – Other than Wet E/C | – On/Off-Board “Computer” |

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SAMPLING OF AUTOMATICS/ROBOTICS “STATUS”

Civilian

- Industrial--increasingly automatic manuf., robots order/deliver products from/to other robots
- Agriculture--increasingly robotic (plowing, fertilization, watering, harvesting, packaging/shipping)
- Space--robotic planetary etc. exploration

Military

- “Fire and forget” missiles
- UCAV's, UAV's, UUV's
- Direct sensor-to-shooter (both robotic)

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Energy/Power Options

- | | |
|------------------------------|---|
| • <u>ON-BOARD</u> | • <u>OFF-BOARD</u> |
| – Batteries | – Beamed MW |
| – Fuel Cells | – Beamed/Natural Photons (PV, Photosynthesis) |
| – Heat Engines | |
| – “Biologics” | |
| – “Blacklightpower”/ LENR's? | |
| – C-nanotube H2 storage | |

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A Reading List

- **Robot - Hans Moravec, Oxford Press/'99**
- **The Age of Spiritual Machines - Ray Kurzweil, Viking Press/'99**
- **The Spike - Damien Broderick, Forge/'01**
- **The Singularity - Ray Kurzweil, to appear**
- **www.imagination-engines.com**

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**For Learning/Adaptive “AI”
[to beyond Human Level]**

www.cyberlife-research.com

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Military/Other Govt. Research of Especial Interest for Exploration

- **Smart/Brilliant/Multi-Functional Materials [DOD, DOE, NSF]**
- **Smart Dust [DOD]**
- **Large “Light Buckets”/Remote Sensing [NRO, USAF]**
- **Moletronics/“Beyond Silicon” [DARPA, NSF]**
- **Robotics including High Radiation Environments [DOD, DOE]**

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Other Govt. (continued)

- **NanoTech [NSF, DOD, DOE]**
- **Micro Air Vehicles [DARPA]**
- **HEDM [DARPA, USAF, DOE]**
- **HPMW [USAF, DOE]**
- **Rad Hardened Electronics/Sensors [DOD, DOE]**
- **NanoSats [DARPA, DOE, USAF]**
- **Space Servicing/Reconfiguration [USAF]**
- **Light Weight Solar Arrays and Space Antennas [USAF]**

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Other Govt. (continued-2)

- **Collaborative Satellite Clusters & Sparse Apertures [USAF]**
- **“Energy Harvesting” [DARPA]**
- **Space Refueling In-flight [DARPA]**
- **High Temp. S-C Electronics [DARPA]**
- **Compact Torroids [DOE, USAF]**
- **Terrabit Fiber Optics [USAF]**
- **High Energy Lasers [DARPA, USAF]**
- **Crycoolers [DARPA, USAF]**

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Other Govt. (continued-3)

- **Composite Cryo Tanks [USAF]**
- **Inflatable/Multifunctional Materials/Structures [USAF]**
- **Light Weight Thermal Protection [USAF]**
- **Adv. Flywheel Storage [USAF]**
- **Ultra-Precision Pointing [DARPA, USAF]**
- **Fuel Cells [DARPA, DOE]**
- **Magnetic Materials [DOE]**
- **Parachutes etc. [DOE]**
- **PROPUL.-IN-THE-LARGE [DOD, DOE]**

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